

THE AEOLIAN WIND TUNNEL

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The aeolian wind tunnel is a special case of a larger subset of the wind tunnel family which is designed to simulate the atmospheric surface layer winds to small scale (a member of this larger subset is usually called an atmospheric boundary layer wind tunnel or environmental wind tunnel). The atmospheric boundary layer wind tunnel is designed to simulate, as closely as possible, the mean velocity and turbulence that occur naturally in the atmospheric boundary layer (defined as the lowest portion of the atmosphere, of the order of 500 m, in which the winds are most greatly affected by surface roughness and topography). The aeolian wind tunnel is used for two purposes: (1) to simulate the physics of the saltation process and (2) to model at small scale the erosional and depositional processes associated with topographic surface features.

A long test section for the environmental wind tunnel is desirable in order to achieve sufficient boundary layer depth, turbulence characteristics, and for the aeolian wind tunnel, equilibrium particle transport rate. Although the side-walls restrict lateral motion of the wind compared to the natural atmosphere, and the turbulent spectrum is "narrower" (i.e., the frequency of the maximum energy containing eddies is higher than for the natural atmosphere), that discrepancy is not as important for sand-sized particles ($> 100 \mu\text{m}$) as it is for modeling transport by suspension (diffusion of dust particles $< 100 \mu\text{m}$). Other important considerations for modeling saltation phenomena include minimum criteria for Reynolds number (u^3/gv , $U_\infty x/v$) and maximum criteria for Froude number (U_∞^2/gH , u^2/gH).

Minimum size requirements for the aeolian wind tunnel are based on the necessity for development of a thick turbulent boundary layer, for equilibrium of mass transport rate as a function of downwind distance, and for (small-scale modeling) the geometric scale ratio desired. The upper limit to wind tunnel size is determined by practicability, available space, and cost. Owen and Gillette (1985) have suggested a lower limit on wind tunnel height based on wind tunnel Froude number. Recent experimental data seem to confirm Owen's criterion of a maximum wind tunnel speed during saltation. The criterion is based on a maximum wind tunnel Froude number, i.e.,

$$(1) \quad \frac{U_\infty^2}{gH} \leq 20$$

where U_∞ is the wind tunnel free stream speed and H the test section height. For Froude numbers above that value, the shear stress, and thus mass transport rate, might not reach an equilibrium value in the wind tunnel. Cermak (1982) has suggested a minimum wind tunnel length criterion based on tunnel length Reynolds number to achieve a thick turbulent boundary layer. His criterion is

$$(2) \quad L \geq 3.47 \delta (\delta U_\infty / \nu)^{1/4}$$

where δ is the desired boundary layer thickness and ν is kinematic viscosity. The minimum test section length for a boundary layer depth of $H/4$ for the aeolian wind tunnel according to these criteria can be found by combining Eqns. (1) & (2):

$$(3) \quad L \geq 0.89 (H^{11} g / \nu^2)^{1/8}$$

For purposes of investigating aeolian effects on the surfaces of Mars and Venus as well as on Earth, the aeolian wind tunnel continues to prove to be a useful tool for estimating wind speeds necessary to move small particles on the three planets as well as to determine the effects of topography on the evolution of aeolian features such as wind streaks and dune patterns.